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The cost of conforming to standard military specifications in an electronic computer system.

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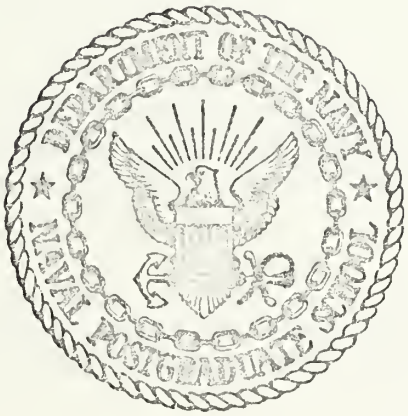

THESIS

THE COST OF CONFORMING TO STANDARD
MILITARY SPECIFICATIONS
IN AN ELECTRONIC COMPUTER SYSTEM

by

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The Cost of Conforming to Standard Military Specifications in an Electronic Computer System

by

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ABSTRACT

This study was undertaken to determine the cost of conforming to standard military specifications in an electronic computer system. The prices of four configurations of a minicomputer system conforming to standard military specifications (MIL-E-16400 and MIL-E-5400) were compared with those of four configurations of an equivalent minicomputer system designed for commercial use. The price differences thus derived were assumed to be the cost of conforming to standard military specifications. These differences represented 42 to 49 percent of the price of the military system considered, depending upon the configuration.

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I. INTRODUCTION

Military equipment used aboard ships, in aircraft or by ground troops is often subjected to hostile or environmentally severe conditions. Standard military specifications have been developed to ensure that equipment purchased by the military is suited to these conditions. According to one such specification, MIL-E-16400F (NAVY):

> "The intent of this specification is to set forth the ambient conditions within which equipment must operate satisfactorily and reliably; the general material, the process for selection and application of parts, and to detail the means by which equipment as a whole will be tested to determine whether it will so operate. . . . Requirements applicable to individual equipment shall be specified in the individual equipment specification."[1]

Conformance with such standard specifications may necessitate new equipment designs or drastic modifications to equipment designed for civilian use. At the time this study was undertaken, little information was available regarding the cost of designing and manufacturing in accordance with standard military specifications. The purpose of this study was to determine the cost of conforming to standard military specifications in an electronic computer system.

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[1] Department of the Navy Military Specification MIL-E-16400F (NAVY), Electronic Equipment, Naval Ship and Shore, General Specification, 24 February 1966, p. 1.

II. METHODOLOGY

Research for this study consisted of locating a military computer system which would lend itself to comparison with a functionally equivalent civilian computer system and gathering technical and price information which would be used to support the comparison.

Initial attempts were made to use either the AN/UYK-7(v) or AN/UYK-20(v) computer systems manufactured by Univac Division of Sperry Rand Corporation as candidates for comparison. Since sufficient technical and price information was not obtainable for these systems, they were by necessity discarded as candidates for comparison. However, the author found certain points related to the AN/UYK-7(v) and AN-UYK-20(v) that were included in the Conclusions and Recommendations Section.

The computer system finally selected was the AN/UYK-12(v) minicomputer system manufactured by Rolm Corporation under a licensing agreement with Data General Corporation and marketed under the brand name Ruggednova 1601. This equipment was identical in function to the Nova brand minicomputer system designed and manufactured by Data General Corporation. The AN/UYK-12(v) or Ruggednova 1601 used the same circuit design and software as the Nova minicomputer system, but the hardware was designed and manufactured in accordance with the applicable military specifications (MIL-E-16400 and MIL-E-5400) for use

aboard ships and in aircraft. Using technical and price information supplied by Rolm Corporation and Data General Corporation, four available system configurations were compared to determine the price difference in each case. Since functional capabilities, circuit design and software were equivalent in the two systems, the price differences thus derived were assumed to indicate the cost of conforming to standard military specifications.

III. EQUIPMENT DESCRIPTION

A. FUNCTIONAL DESCRIPTION

The Ruggednova 1601 and Nova minicomputer systems are organized around four 16-bit hardware accumulators, two of which may be used as instruction registers. The central processor is the control unit for the entire system and governs all peripheral in-out equipment, performs all arithmetic, logical and data handling operations and sequences the program. The central processor handles words of 16-bit length which are stored in a memory with a maximum capacity of 32,768 (32K) words. Memory cycle time is 2.6 microseconds and logical and data handling instructions are executed in 5.6 microseconds. The central processor has a 16-level programed interrupt and a direct memory access data channel. This latter feature allows a high speed device such as magnetic tape or disk to gain direct access to memory through a data channel without executing any instructions [Refs. 2 and 5].

Both systems use the same instruction set and software. Available software includes an assembler, relocatable assembler, cross assembler, text editor, debugging package, relocatable link loader, BASIC, extended ALGOL, extended FORTRAN IV, mathematical routines, floating point interpreter, diagnostics, real-time operating system and disk operating system [Refs. 2 and 3].

B. RUGGEDNOVA 1601 SYSTEM SPECIFICATIONS

The Ruggednova 1601 minicomputer system was designed to conform to standard military specifications MIL-E-16400 Class IV for use aboard ships and MIL-E-5400 Class II for use in aircraft [Ref. 3]. These specifications called for the use of unitized modular construction, miniaturization, printed wiring boards and plug-in techniques [Ref. 1]. The inspection program was set up to meet standard military specification MIL-I-45208A and quality assurance programs were set up along the guidelines of standard military specification MIL-Q-9858A [Ref. 3].

A description of the manufacturing process used to ruggedize the circuit modules used in the Ruggednova 1601 minicomputer system is included in Appendix A.

The Ruggednova 1601 minicomputer system was designed to meet the following manufacturer's specifications [Refs. 3, 4, and 5].

1. Size

The central processor measured 7.62"H × 10.12"W and varied in depth from 15.76" to 18.96" depending upon the configuration. The control panel measured 7.75"H × 10.12"W × 3.77"D. The external memory chassis, where required, measured 7.62"H × 10.12"W × 27.36"D.

2. Weight

The total system weighed approximately 47.5 pounds in the basic unit configurations and 92 pounds in the extended memory configurations.

3. Power Requirements

The system required 115 VAC, 400 Hz input power.

4. Temperature Range

The standard operating temperature range was from 0°C to 65°C. An optional wide temperature range (-25°C to +75°C) and an extreme temperature range (-55°C to +95°C) were available at extra cost. The system could be stored at temperatures from -65°C to +125°C.

5. Heat Dissipation

Sufficient circulation must be provided to absorb a maximum of 275 watts of heat.

6. Humidity

The system was designed to operate at up to 95 percent humidity with condensation present.

7. Altitude

The system was designed to operate at altitudes up to 80,000 feet.

8. Reliability

The system has a calculated mean time between failures of 11,000 hours.

9. Vibration

The system was capable of withstanding 3g's maximum acceleration from 5Hz to 1KHz without vibration isolators and 10g's maximum acceleration from 5Hz to 2KHz with vibration isolators.

10. Shock

The system was capable of withstanding 15g peak half sine wave acceleration with 11 millisecond duration. In

addition, the system has passed the requirements of standard military specification MIL-S-901 which required a 900-pound hammer swung through a 5-foot arc to impact against the side of the cabinet.

11. Miscellaneous

The system was designed to be sand, dust, salt spray and salt fog resistent.

C. NOVA SYSTEMS SPECIFICATIONS

The Nova minicomputer system was designed to meet the needs of the average commercial user. Unitized modular construction, miniaturization, printed wiring boards and plug-in techniques were also utilized in the construction of the Nova system [Ref. 2].

The Nova minicomputer system was designed to meet the following manufacturer's specifications [Refs. 2 and 6].

1. Size

The central processor measured 5.25"H × 19"W × 20.25"D with the operator's console mounted on the front. The expansion chassis, where required, measured 5.25"H × 19"W × 20.25"D.

2. Weight

The total system weighed approximately 60 pounds in the basic unit configurations and 100 pounds in the extended memory configurations.

3. Power Requirements

The system required 110 VAC, 47 to 63 Hz input power with a voltage tolerance up to 10 percent.

4. Temperature Range

The recommended ambient temperature for the system was +20°C to +30°C, although the temperature could vary between 0°C and +55°C without adverse effects. The system could be stored at temperatures as high as +70°C.

5. Heat Dissipation

Sufficient circulation must be provided to absorb a maximum of 400 watts of heat.

6. Humidity

The system could be operated at up to 90 percent humidity, with no condensation present. Although exposed surfaces were treated to prevent corrosion, exposure to extreme humidity for long periods of time was not recommended.

7. Altitute

Exact information as to the altitute capability of the system was not available, but a later model Data General Corporation system, the Nova-2 may be operated at altitudes up to 10,000 feet and stored up to 50,000 feet [Ref. 7]. The Nova system was assumed to have comparable altitude capabilities.

8. Reliability

Exact information as to the reliability of the system was not available, but the Nova-2 system has a calculated mean time between failures of 7,255 hours [Ref. 7]. The Nova system was assumed to have comparable reliability.

9. Shock and Vibration

Shock and vibration specifications for the Nova system were not available from the manufacturer. The author was unable

to obtain any industry standards or comparable system specifications which would provide an indication as to the ability of the Nova system to withstand shock and vibration.

Summary specification data is presented in Table I.

TABLE I

SPECIFICATIONS

	Ruggednova 1601	Nova
Size		
Central Processor (Maximum)	7.62" × 10.12" × 18.96"	5.25" × 19" × 20.25"
Control Panel	7.75" × 10.12" × 3.77"	--
Operator's Console	--	Included in CPU
External Memory Chassis	7.75" × 10.12" × 27.36"	--
Expansion Chassis	--	5.25" × 19" × 20.25"
Weight		
Basic Unit Configuration	47.5 lbs.	60 lbs.
Extended Memory Configuration	92 lbs.	100 lbs.
Power Requirements		
Voltage	115 VAC	110 VAC ± 10%
Frequency	400 Hz	47-63 Hz
Temperature Range		
Operating	0°C- + 65°C	0°C- + 50°C
Recommended	--	+20°C- + 30°C
Storage	-65°C — +125°C	Up to +70°C
Heat Dissipation		
Maximum	275 Watts	400 Watts
Humidity		
Maximum	95%	90%
Condensation Present	Yes	No
Altitude		
Maximum Operating	80,000 ft.	Unknown
Reliability		
Calculated MTBF	11,000 hrs.	Unknown
Vibration		
Without Vibration Isolators		
Force	3g's	Unknown
Frequency	5Hz - 1KHz	Unknown
With Vibration Isolators		
Force	10g's	Unknown
Frequency	5Hz - 2KHz	Unknown
Shock		
Force	15g's	Unknown
Duration	11msec	
Miscellaneous	Sand, Dust, Salt Spray, Salt Fog Resistant	Unknown

IV. PRESENTATION OF DATA

A. SOURCES

System configuration and price information for the Ruggednova 1601 and Nova systems was obtained from technical descriptions and price lists [Refs. 2 thru 6] furnished by the manufacturers, Rolm Corporation and Data General Corporation, respectively. All information furnished was current as of October 1973. Both firms offer quantity discounts on all equipment considered, but those discounts would vary according to the quantity purchased, hence they were not considered in determining the prices used in this study.

B. SYSTEMS CONFIGURATIONS

In order to provide for the evaluation of both basic and optional components, four systems configurations were selected for consideration. These configurations were felt to be representative of the spectrum of equipment available in both the Ruggednova 1601 and Nova systems and typical of configurations desired in military systems.

1. Basic Unit

Included in this configuration were central processor, control panel or operator's console, power monitor and automatic restart capability and 4096 bytes of 16-bit memory (4K).

2. Basic Unit with Extended Arithmetic Capability

Included in this configuration were all of the components of the basic unit plus an extended arithmetic unit. The

Ruggednova 1601 system extended arithmetic unit was not directly compatible with the Nova system extended arithmetic unit software, but both units provided a hardware multiply-divide capability at comparable execution speeds.

3. Extended Memory System

Included in this configuration were all of the components of the basic unit plus 28,672 bytes of memory (28K) for a total of 32,768 bytes of memory (32K). The extended memory of this configuration was achieved by the addition of seven 4096 byte (4K) memory modules which required an external memory chassis for mounting in the Ruggednova 1601 system and an expansion chassis for mounting in the Nova system.

4. Extended Memory System with Extended Arithmetic Capability

Included in this configuration were all of the components of the basic unit plus 28,672 bytes of memory (28K) and an extended arithmetic unit. As in the previously presented configurations, the additional memory required an external memory or expansion chassis for mounting and the extended arithmetic unit of the Ruggednova system was not directly software compatible with the Nova system extended arithmetic unit.

Summary configuration data is presented in Table II.

C. COMPARATIVE DATA

Using the price information provided, comparative prices for the selected configurations were determined as follows:

TABLE II

CONFIGURATIONS

	Central Processor	Control Panel or Operator's Console	Power Monitor & Automatic Restart	4K Memory	32K Memory	Extended Arithmetic Unit
Basic Unit	X	X	X	X		
Basic Unit with Extended Arithmetic Capability	X	X	X	X		X
Extended Memory System	X	X	X		X	
Extended Memory System with Extended Arithmetic Capability	X	X	X		X	X

1. Basic Unit[2]

Ruggednova 1601

Central Processor	$7,500	
Control panel	2,250	
Memory module (4K)	6,000	
Total		$15,750

Nova

Central processor	$3,950	
Power monitor and autorestart	400	
Memory module (4K)	3,650	
Total		8,000
Increase		$ 7,750
Percentage increase		96.9

[2]The power monitor and automatic restart capability is provided with the Ruggednova 1601 system as standard equipment, but is optional with the Nova system. An operator's console is provided with the Nova central processor unit, but a control panel which performs the same function must be ordered separately for the Ruggednova 1601 system.

2. Basic Unit with Extended Arithmetic Capability

Ruggednova 1601

Central processor	$7,500	
Control panel	2,250	
Memory module (4K)	6,000	
Extended arithmetic unit	3,500	
Total		$19,250

Nova

Central processor	$3,950	
Power monitor and autorestart	400	
Memory module (4K)	3,650	
Extended arithmetic unit	2,000	
Total		10,000
Increase		$ 9,250
Percentage Increase		92.5

3. Extended Memory System

Ruggednova 1601

Central processor	$ 7,500	
Control panel	2,250	
Memory modules (8x4K)	48,000	
External memory chassis and wiring	3,300	
Total		$61,050

Nova

Central processor	$ 3,950	
Power monitor and autorestart	400	
Memory modules (8x4K)	29,200	
Expansion chassis	1,850	
Total		35,400
Increase		$25,650
Percentage increase		72.5

4. Extended Memory System with Extended Arithmetic Capability

Ruggednova 1601

Central processor	$ 7,500	
Control panel	2,250	
Memory modules (8x4K)	48,000	
External memory chassis and wiring	3,300	
Extended arithmetic unit	3,500	
Total		$64,550

Nova

Central processor	$ 3,950	
Power monitor and autorestart	400	
Memory modules (8x4K)	1,850	
Expansion chassis	29,200	
Extended arithmetic unit	2,000	
Total		37,400
Increase		$27,150
Percentage increase		72.6

Summary comparative price data is presented in Table III.

TABLE III

COMPARATIVE PRICES

	Ruggednova 1601	Nova	Increase	Percentage Increase	Increase as Percentage of Ruggednova Price
Basic Unit	$15,750	$ 8,000	$ 7,750	96.9	49.2
Basic Unit with Extended Arithmetic Capability	19,250	10,000	9,250	92.5	48.0
Extended Memory System	61,050	35,400	25,650	72.5	42.0
Extended Memory System with Extended Arithmetic Capability	64,550	37,400	27,150	72.6	42.1

V. CONCLUSIONS AND RECOMMENDATIONS

The cost of conforming to standard military specifications in the systems which were considered in this study may be less than that of larger and more complex systems. The reason for this is the simplicity of the Ruggednova 1601 system. It utilizes a closed cabinet and no fans or coolant are used to remove heat [Ref. 3]. The larger and more complex AN/UYK-7(v) and AN/UYK-20(v) use open cabinets and fans for cooling [Refs. 8 and 9]. This factor may be the cause of further cost increases. The fans and attendant ventilation devices must be designed and manufactured according to the applicable standard military specifications and the internal parts may have to be protected to a greater degree because of the open cabinet design. Further study would be necessary to determine if this is in fact the case.

The major conclusion of this study was that the requirement to conform to standard military specifications was a major factor in the price of the military computer system considered in this study. As shown in Table III, this requirement accounted for 42 to 49 percent of the price of the Ruggednova 1601 system.

It is recommended that this factor be considered in the procurement of future military computer systems. In addition, the following three proposals for reducing the cost of military computer systems are presented as possible topics for further study and evaluation.

1. Revise present standard military specifications for all electronic computer systems to be used aboard ships and in aircraft. Because of the high costs involved in conforming to these specifications, significant cost savings might be achieved by reducing the present requirements only slightly. Of course any benefits derived from the reduction in requirements would have to be weighed against the resultant loss in the mission effectiveness of the system.

2. Revise present standard military specifications for electronic computer systems to be used aboard ships and in aircraft but which are not combat essential. If present requirements for combat essential electronic computer systems could not be reduced without causing an unacceptable loss in the mission effectiveness of the system, then perhaps the requirements for equipment which is not combat essential could be reduced without reducing the mission effectiveness of the ship or aircraft as a whole while reducing the cost of equipment.

3. Achieve required reliability through increased redundancy and use of less rigidly specified equipment. An alternative to requiring that each piece of equipment be capable of withstanding the worst conceivable conditions might be to provide a system which is capable of withstanding such conditions. For example, in the situation where the redundancy of two electronic computer systems is required for reliability, instead of providing two rigidly specified units, provide three less rigidly specified units. This could provide

more capability under normal conditions and produce the required level of reliability in critical situations at less cost.

APPENDIX A

RUGGEDIZED CIRCUIT MODULE MANUFACTURING PROCESS

The manufacturing process begins with the purchase of printed circuit modules containing wide temperature ceramic integrated circuits which conform to the applicable standard military specifications and Data General Corporation circuit designs. To each of these modules a thermal frame is added to conduct heat away from the integrated circuits and stiffen the module. Fork type connectors are then attached to the module to ensure contact under vibration. Between these connectors an alignment block is placed to provide support for the center of the board and prevent plugging the module into the wrong slot. Finally, the entire module is covered with an aluminum stiffener which is attached at four points to the center of the module to prevent "oil canning" during vibration. These ruggedized modules are then clamped inside the cabinet with a wedge which acts as a thermal connector and allows removal of the module by removing four screws [Ref. 3].

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